

# WallBots: Interactive Wall-Crawling Robots

## In the Hands of Public Artists and Political Activists

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### ABSTRACT

Street art and political activism have a rich history of shaping urban landscapes. Our work explores the processes by which public artists and political activists contribute to public spaces, introducing opportunities for HCI researchers to engage with the people who shape the aesthetic feel of our cities. We present WallBots-autonomous, wall-crawling robots as a research probe for public expression across a wide range of surfaces and hard-to-reach places, including bus stops, whiteboards, streetpoles, trashcans, moving vehicles and building walls. We evaluate WallBots as a low-cost DIY authoring tool for public artists and activists. Our study of six individuals who extensively contribute to public spaces offers insights into the materials and practices behind grassroots public expression. We then leverage feedback from participants, among them a graffiti artist, light painter, political activists, and street musician, to evaluate interaction techniques for manipulating WallBots as a medium for public expression across a range of surfaces. Our findings expose a research space for technological interventions in the context of street art, and we conclude with design insights for magnetic kinetic systems as an approach for supporting engagement, expression and creativity in public spaces.

### Keywords

Autonomous agents, public spaces, street art

### INTRODUCTION

*"People look at an oil painting and admire the use of brushstrokes to convey meaning. People look at a graffiti painting and admire the use of a drainpipe to gain access."*

*-Banksy*

Public spaces present a natural canvas for expression, provocation and creativity. City streets worldwide have a rich history of fostering artistic and political subcultures, from graffiti artists, to street performers, to environmental activists, challenging our notions of anonymity, authorship, physical boundaries, political freedoms, and social convention [25]. Whether we like it, hate it, or ignore it, street art plays into urban aesthetics. It shapes the way we feel and engage in the spaces around us.

So who are the people that tape posters to streetpoles, paint murals on buildings, spraypaint words in underpasses, and sing in subways? What are their goals, their challenges and their needs? And how can we, as HCI researchers contribute to the practices that shape our cities? As an emergent body of HCI literature explores authorship in

public spaces [6, 9, 13, 19, 20, 26, 38] we look for convergence between grassroots public expression and low cost technologies. Our work explores opportunities to engage the graffiti artist, the street musician and the activist in the design of interactive systems for public expression.

We present WallBots, autonomous magnetic robots that can freely traverse any vertical steel surface, as a research probe for activating a range of public spaces and ‘third-places’, including bus stops, hallways, trashcans, streetpoles, elevators, stairways, etc. (Figure 1). Built entirely from inexpensive over-the-counter parts, WallBots can be easily replicated and modified by non-experts, allowing artists, political activists and general hobbyists to leverage wall-moving robots as a novel platform for expression and authorship. While public authorship and citizen participation is our long-term goal, in this paper we explicitly explore the role of early adopters and “skilled city authors” such as artists and activists in engaging with such expressive public technology. We evaluate our approach in a study of six individuals who already contribute to public spaces through graffiti, paint, street music, political flyers/posters, and light graffiti.

The first part of our study explores mechanisms by which artists and activists currently contribute to public spaces, including their motivations and their challenges. We scope our research around eight surfaces that can be used to host WallBots, among them trashcans, building walls, and bus stops. Participants are then introduced to WallBots through hands-on demos as well as videos of interaction techniques that can be used to manipulate the movement and appearance of wall-crawling robots. Our work presents participants’ feedback and ideas about possible uses of and interactions with WallBots in the context of their work. Drawing from an extensive tradition of participatory and iterative design research [2, 28, 33, 39], we leverage our findings to inform the development of low-cost autonomous agents as an authoring tool for public artists and activists.



Figure 1. WallBots deployed on building façade (right) and on fire hydrant (left).

## Research Objectives

An overview of related work in autonomous agents and authoring tools for public spaces inspires the design of our WallBot prototype. We position WallBots as a novel, low-cost, easily-reproducible (DIY) platform for any multi-agent sensing and interaction on vertical, eye-level spaces. Our work includes a vocabulary of interaction techniques that can manipulate the behavior and appearance of WallBots. We evaluate WallBots as an authoring tool for public surfaces through a study of six fascinating individuals including a graffiti artist, a street musician, political activists, and a light-painter. Semi-formal interviews with our participants reveal the processes and tensions that shape urban landscapes, suggesting design opportunities for technical interventions in the context of street art and activism. We conclude with design recommendations for activating public spaces and vertical surfaces with novel pervasive technologies, specifically through the use of autonomous, intelligent agents.

## RELATED WORK

Prior work has deployed horizontally-moving (on the ground plane) robots into everyday environments in order to assist, provide social company, inform or entertain the user [8, 23, 36]. Ground-moving robots have also been leveraged to probe urban experience [29, 30] and to empower community-wide participatory sensing and expression [14, 20]. We contribute to this research by exploring vertical mediums for robot placement, allowing for flexible and unobtrusive deployment that avoids several common challenges of traditional, horizontal-moving robots: interfering with traffic, being stepped on, not being noticed at all, etc.

Dautenhahn derives the concept of ‘socially intelligent agents’ as a new design space for interactions between autonomous sociable robots and humans [18]. Several projects revealed human reflections on machine intelligence in private homes, including a study of Tableau Machine [42]— an autonomous visualization for smart homes, and people’s evolving relationships with the Roomba vacuum [24]. Using these and many other examples of perceived robot intelligence, Taylor proposes ‘machine intelligence’ as a novel domain for human-computer interactions [48]. We therefore present WallBots-robots that allow for machine intelligence on the vertical plane, a domain that has remained unexplored by prior work in autonomous agents. Leveraging elements of creative play [41] and inquisitive use [15] we inform the design of autonomous, kinetic agents as a public resource for activating, provoking and authoring vertical surfaces.

## Flexible Modular Design

We draw inspiration from several systems that enable modular placement and activation of independent interactive elements: Pushpin Computing [35]— a platform for computation and visualization with small nodes, DataTiles [37] and Siftables [44] which consist of separable tile displays; SoundMites [7] and Throwies [34]— small magnetic devices that enhance surfaces with sound

(former) and LED lights (latter) Urban Pixels, modular wireless light fixtures that allow for interactions with individual pixels as well as the collective display [47], and most recently SMSingshot which allows users to ‘throw’ content onto large public displays [22]. We apply these flexible and modular design paradigms of past systems to our concept of WallBots, independent robots that adhere to any steel or iron surface and autonomously respond to events in the environment.

## Interactions in Public Spaces

Public spaces have attracted a range of interaction techniques that aim to socially connect, inform and entertain users, ranging from large displays and projections to interactive walls, floors, and multi-modal visualizations and large media façades [6, 9, 13, 16, 17, 31]. Numerous systems rely on human touch, for instance, the Viscous Display enables users to activate public spaces with a low-cost flexible displays mimicking ‘underground public art’ [47] while IKE implements control over a virtual kite through interactions with physical ropes [1]. Off-surface interactions explored flashlight input in the context of collaborative public games [10] and spatial sensing [43] as well as audio localization, gestures and face detection [12]. Cobots rely on implicit and explicit input, drawing on surfaces in response to gestures and ambient sounds from the audience [11].

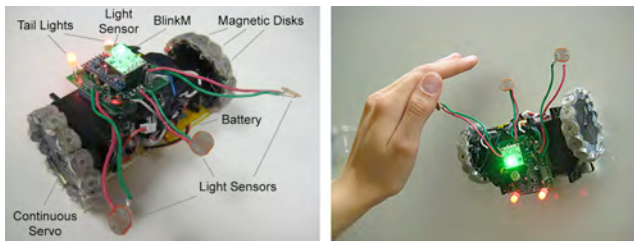
Moreover, numerous public installations detect and react to ambient input: VUPoints identifies pivotal social events through ambient monitoring, automatically recording interesting videos that can then be shared with the group [5], and Vogel *et al.* explore ambient, implicit and personal interactions with large public displays, offering finer control of visualizations (through gesture and touch) based on user proximity [50] to name a few. Mobile phones have also been leveraged to activate large displays in the context of public games [4] seamless data navigation [3] public image sharing [21] and democratic music selection [32], among others. Sakamoto, *et al.* explore remote interactions by allowing users to control home robots through a sketch interface on the computer [46].

Drawing from input methods that have been leveraged by past systems, we introduce a simple vocabulary for interactions with robots on vertical surfaces. We categorize input based on proximity to surfaces as well direct and ambient modalities. We illustrate each category with examples and evaluate possible applications in the context of authoring vertical surfaces with WallBots.

## WALLBOT DESIGN

We developed two prototype magnetic robots that we call WallBots. These robots have two wheels with (commercially available) magnetic disks glued around each rim, allowing WallBots to defy gravity. Wheel rims are covered with silicone paste to increase traction as robots traverse vertical surfaces in any direction. A continuous servo motor drives each wheel, as two rechargeable lithium batteries power the robot. WallBots are controlled by an

Arduino Mini— an open microcontroller that is widely used in numerous art projects for its flexibility and easy programming (for example, to control Jackson an artbot that paints on horizontal canvases [49]) We printed a custom circuit board to connect and house the electronics, allowing for accessory sensing and expression capabilities, as additional electronics can be attached directly to the board. For instance, our PCB design includes slots for a BlinkM – a powerful pic-controlled tri-colored LED that can be easily programmed for any color, pattern or fade sequence, to express the WallBot through light. The back of the board houses slots for LED’s, which we have implemented as tail lights to playfully indicate WallBot turn direction.



**Figure 2. WallBot design, with parts labeled (left) and a user casting a shadow on the robot’s left light sensor (right).**

In addition, our board leverages Arduino’s analog pins such that any four sensors can provide input to the WallBot (light, noise, tilt, temperature, etc). Our first prototype, includes four photoresistors (light sensors), placed on the front-right, direct-front, front-left, and top of the robot (Figure 2). Continuous sampling from these sensors enables robots to detect light gradients in the environment and react to hand gestures. The WallBot are programmed with as USB-TTL cable, which connects directly to our PCB.

**WallBots in the Context of Street Art**

We envision WallBots as a technology that can be easily replicated, modified, and deployed by public artists and activists. Given the low cost, easy construction and flexible (programmable) behavior of WallBots, we position our technology as an authoring tool for people who shape our cities through art and political activism. In doing so, we aim to open a broader dialogue between HCI research and grassroots public expression. We begin with an exploration of the current practices, methods, and motivations of public artists and activists.

**URBAN EXPRESSIONS: PRACTICES AND METHODS**

To gain insights into the processes that drive public art and activism, we conducted a study of six participants who extensively contribute to public spaces. The study consisted of semi-formal interviews that investigate three themes: 1) participants’ current work, goals, and obstacles in public spaces, 2) participants’ expressions across eight surfaces that could serve to house WallBots, and 3) participants’ evaluation and appropriations of WallBots and interaction techniques that could be used to control them. Participants were recruited through an online bulletin board (Craigslist)



**Figure 3. Example public expressions from our participants (left to right): Mandala painted on sidewalk, “save our library” flyers on library, light painting on building window.**

and compensated \$10 upon completing the interview, which lasted for about an hour.

**Participants**

Our 6 participants contribute to public spaces for political (P2, P3), artistic (P1, P4-6) and/or financial (P6) reasons (see Table 1 for participant details and Fig. 3 for examples of their work). P1 has been doing graffiti for over 10 years, “from hand-tagged stuff to full-on graffiti”; P2 and P3 post flyers and posters for presidential campaigns and local projects (e.g., “save our libraries”- to keep local libraries open); P4 paints “with light in a long-exposure photograph, and the whole time I’m moving light around and it’s creating an image”; P5 works with a variety of materials, including typewriting poetry on tree leaves and “leaving them anonymously in places”, spray-painting stencils, graffiti, and flyers (eg. Buddhist Thoughts) with a “wake up now, life is now” message; and P6 plays guitar and sings, often “busking”- performing for tips especially in “affluent, south of the city suburbs”. None of the artist participants had political agendas (“I try to stay out of it, I’m not a big fan of politics”, P4; “I just believe in love, peace and harmony and that’s not political”, P5), contributing to public spaces for “self expression” or “public attention”. In addition, the street musician (P6) was motivated by money: “It’s a balanced interest. The money is great, but it’s also fun, summer memories”.

Participants tend not to use their real names during public expression, however P1 and P5 sign their work with a symbol: “I have a symbol that I use, that I think people recognize”, and P4 often writes “the name that I have for my website” P4. P1 is particularly inspired by hard-to-reach places “climbing places, rooftops, the most inconvenient places that you would ever expect to see it”, enjoying peoples’ reactions: “I kinda like when people are walking down and they see something like up on a roof... up high- the higher the better. People will be surprised when they see it: How the hell did he do that, how did he not fall, how did he not get caught...”. P5 also observes public reactions, for instance: “I took straws and I hung them around different places outside in a city and they just said breathe... it was so fascinating to watch people interact with them.... Some people would stop and [*inhaling emphatically*] take a deep breath and that was

	Public Contribution	Primary Motivation
P1	Grffiti	Public expression, attention
P2	Political flyers/posters	Political message
P3	Political flyers/posters	Public expression
P4	Light-graffiti	Public expression
P5	Misc. art, music, graffiti	Public expression
P6	Street music	Public expression, money

**Table 1. Study participants.**

kinda the point... and also people who wanted to take them, and that moment between taking it and leaving it for someone else to experience". P2 and P3 gauged the effectiveness of their flyers based either on rally turnouts (e.g., "we had such a turn out- without all the flyers notifying people there is no way people would've known about it"), or direct observation: "some people stopped there and then read a little bit and then turned away- maybe to register to vote or something, but some people brushed aside and went ahead" (P2).

#### *Conflict with Authority*

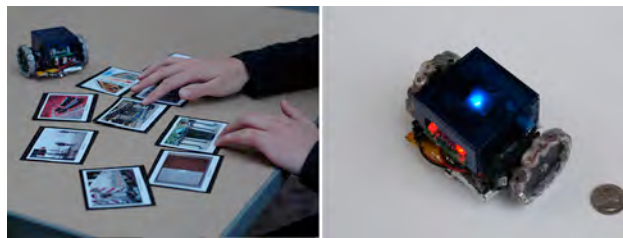
To varying extents, all participants experienced tensions with authority. P1 and P5 were most affected: "graffiti is kind of like a rush to me, there's always that risk, you could get seen, you could get caught, you never know when someone could come up behind you..." (P1); "you have to be careful in America because they'll arrest you and put you in jail... I find myself resorting to sides of buildings or places where I have more coverage" (P5). In the past, P6 and P4 have both been "chased out" or "kicked out" by the police (e.g., "I tried the PPG [skyscraper] place before, but security is a little tight, apparently you're not allowed to have a tripod there. I think it's like an anti-terrorist thing, I've been kicked out of there more than once", P4). To a lesser extent, activist participants faced similar problems: "sometimes the management or facilities just strip out all the posters and so mine is gone too" (P2), or in the context of permission to place posters: "some businesses are just kinda like, yea it's a great idea but we don't wanna junk up our wall or window or whatever" (P3).

#### *Materials and Money*

Participants tend to create or repurpose their materials. The activists usually design and print their own posters. P5 prefers "taking things from nature", not killing anything but using "things that are already on the ground" (eg. printing poetry on dead leaves), as well as recycled materials such as straws or shredded paper. P1 changes the intended function of tape to author street surfaces with designs "that wasn't part of the street or public transit or something". In addition, P1 either makes paints from scratch (using simple household products for instance) or receives materials for free: "never spent a dime, either making my own stuff or coming about companies online that make certain types of markers or certain types marking materials or paint", and asking companies for free samples of their products. P6 also highlights the importance of money: "On a good night you can make like 50 bucks playing for a couple of hours".

#### **Surfaces**

We scoped our study around eight surfaces, which could serve for WallBot placement and interaction. Participants were shown images and asked to comment on their uses and perceptions of each space (Figure 4). Their feedback highlights tensions between public and private property, as well as visible and anonymous expressions.



**Figure 4. Participant discussing expressions across public surfaces (left) and WallBot with casing (right).**

#### *Bus Stop*

Bus stops are pervasive throughout urban landscapes, often serving as 'third-places' for crowds of familiar strangers [40]. On one hand, the space presents an audience for flyers and messages: "if you're actually writing something, any sort of message you wanted to get across it would be really good place to do so" (P5). P1 enjoyed placing graffiti there, "towards the bottom... Noone would see you, you could walk away, but then someone else would sit down look around and catch it out of the corner of their eye and see what it is". Conversely, P6 (street musician) disliked "foot-traffic": "it's also very loud... you kinda need to find a place that's not by a lot of traffic otherwise you're competing with the traffic."

#### *Park Bench*

We selected this surface as an intersection between city and nature, and participants' feedback highlights tradeoffs between "seclusion" and attention. P1 took advantage of the less visible space: "I could just sit down... get something written [on the bench] between my legs, and then someone else would sit down and when they look down it's gonna be right there". P6 also liked this surface: "Park bench is ideal: you can just put your case out and play", and P4 has used it for light graffiti: "I shined the light on different areas of the bench so that it shows up in different colors and then you can do a number of designs on top of that". Conversely, activist participants preferred something "a little more visible" (P3) and did not put flyers there: "It[flyer/poster] isn't supposed to be there" (P2).

#### *Building Wall*

Walls define urban landscapes, and comments from participants suggest a tension between public and private property: P3 has "never done anything big like that, I would've talked to the owner or manager first... you don't want people to look at it and just go, well that's just graffiti and they're ruining the [building]", and P1 placed graffiti "only on business walls— something that's not a house. It's just disrespectful to property owners... you wouldn't want someone writing on your house, why would you write on someone else's [house]".

#### *Trashcan*

This ubiquitous piece of urban furniture invited different interpretations between artists and activists. Activist participants did not perceive it as an appropriate medium, P3 suggesting "it might say something about the message", and P2 feeling most strongly: "trashcan is the number one

worst place... I wouldn't touch a trashcan". Artists were more receptive: "I have actually seen some light drawings done with a trashcan where it was kinda made to look alive, it had a face and whatnot and arms" (P4), and P1 liked its "smooth surface, you can stick something to it", as well as its visibility: "definitely the garbage men are gonna see it, but depending on where they're at, the public walks by... someone's gonna see it". P5 has left food "around the lip: "it means that someone else can take it" and placed "positive encouraging things around recycling".

#### Moving Vehicles

As with building walls, moving vehicles presented a tension between "personal" and "business", as noted by P1: "cars like personal, suv's, trucks and all that no, 18-wheelers yea". The bounded space inside posed a problem for street music: "One thing about doing it in a public space is that people have the right and the option to opt out—they can just keep walking... but if you're riding on a bus or something like that, people do not have the choice". Nevertheless, participants considered vehicles in their work for publicity ("when you're waiting [for a bus], you have a captive audience... you're sitting there watching it go past, you're bound to read it", P3), motion ("love that stuff cause it moves on its own, I don't even have to worry about it, I love the trails that I can get from long exposure", P4), and surrounding airflow ("a friend and I had shredded paper, and we released it [in a subway tunnel]... it's just like this huge flurry of dancing paper, it was beautiful", P5).

#### Streetpole

Participants felt that it was generally acceptable to place flyers and art on a street pole, but expressed concerns about shape, noise and visibility. Shape dictates flyer layout: "the shape of the flyer becomes more of an issue. If you're putting it on something round... just to make sure you can actually see what it says" (P3); surrounding noise affects street music: "people have their windows down, they'd be blaring their music, so you're competing with that for attention" (P6); and lastly, visibility increases the risk of getting caught "there's a light on it, there's a light on you, you gotta be quick with it" (P1).

#### Bulletinboard/Whiteboard

Bulletin/white boards exemplify semi-public 'authorized' surfaces, and activist participants routinely used them for flyers. Artist participants tended to "doodle" but most were not inspired to use boards for significant projects: "wouldn't see the point necessarily" (P4).

#### Elevator

Elevators present another semi-private space, often characterized by a captive audience. P2 and P3 felt comfortable placing posters there ("if I have tape then I can post something", P2), and P5 was fascinated by "photography in elevators because it's a temporal space, people are coming and going". The other participants have not seriously considered working in elevators: "if people walk in an elevator and I'm there, they'll just think I'm a jerk" (P6) and because "most of them have cameras" (P1).

#### Other Surfaces

A blank card was provided to invite participants to suggest other surfaces. Responses included windows (P3), escalator (P2), steps (P6), parking meter (P5), and trees (P4).

#### MANIPULATING WALLBOTS ON PUBLIC SURFACES

We present a simple vocabulary to discuss interaction techniques that can manipulate WallBots across the previously discussed surfaces (Table 2). Interactions are classified spatially: *with object*— with the WallBot itself, *on surface*— with the surface that houses the WallBot, or *off surface*— removed from the surface; and semantically: *explicit*— with direct instructions, or *implicit*— the robot interpreting one or several input modalities in its surroundings. Videos demonstrating 'Wizard of Oz' examples of each approach (except cellphone/website) were shown to participants, and we now detail their feedback for each input method.

	Explicit	Implicit
With Object	Programmable Movement	Gesture
On Surface	Draw Input	Knock Input
Off Surface	Verbal Instruction Cellphone, website	Following a Person Ambient Sound

Table 2. Example interactions techniques for public surfaces.

#### Programmable Input (Explicit, With Object)

This method allows users to 'program' the WallBot by physically motioning it through a sequence of desired movements, thus explicitly and physically interacting with the object itself. Generally, participants did not find this method useful because it implies that 1) the WallBot must stay within reach: "If you could show it how to move, you could walk off with it" (P1), and 2) it can only do things that can already be accomplished by a human: "if I could do it, I don't need the robot to do it" (P3).

#### Gesture (Implicit, With Object)

Rather than specifying a set of actions, users can indicate movement direction with a gesture (e.g., our demo video showed a WallBot following a users' hand). Participants preferred this implicit with-object approach for its fluidity ("you're just going like this [motioning with hand] and it's doing it for you", P3), as well as for its intuitiveness ("best way for someone else to interact with it because they don't know how else to make it [move] – just put their hands near it and it starts to move", P6), and also for its playfulness (P1 suggested placing it "at a retaining wall at a park—almost like a child interaction. Kids could spend hours playing with that"). In addition, P5 saw this technique as a "communicative tool for deaf people" – who naturally 'talk' through gestures, and P4 envisioned a photography piece: "fire the flash— see the person in different frames creating the motion... an image superimposed on itself several times in different places at different frames".

### *Draw Input (Explicit, On Surface)*

One of the most preferred amongst all participants, this method consists of drawing an explicit path for the WallBot to follow (implemented via a camera feed or acoustic sampling [27], for example). Several people immediately noted a “performative” (P5) aspect, since the interaction demonstrates “not just creating it[art] but how it’s created, what’s being done” (P1), thereby forming “a performance— like interaction of the artist and the robot as part of the performance” (P3). Moreover, this approach enables authorship in harder-to reach surfaces, due to precise control remotely from the WallBot itself, “to make something on the outside of a train there’s often not a lot of time... it can allow for artwork on the outside... especially if you could form a relationship with it from the inside of the train and then guide it” (P5). Draw input also suggests the option of controlling a WallBot “where someone is not gonna go and take it, so also out of reach for people” (P1). Lastly, this method suggested creative play in third-spaces: “it would be really cool to have a bus stop while you’re waiting for a bus and you could play with a robot and just draw stuff and it would draw” (P3).

### *Knock Input (Implicit, On Surface)*

This approach allows users to communicate with WallBots by knocking on the underlying surface, presuming the WallBot can interpret a knock-vocabulary through audio or vibration sampling. Participants perceived this interaction as “a variation of the voice command, probably not as useful as a voice command” (P3). However, its ambiguity also reduced risks, “So much more secretive [than voice]... in a way it could totally free a street artist from having responsibility” (P5), and invited interpretive play: “if there was a sign that said knock on the wall move the robot. I’m sure you would have people there all day long” (P1).

### *Verbal Instruction (Explicit, Off Surface)*

Here, users explicitly verbalize commands to the WallBot (e.g., “go forward”, “turn right”, etc.) Participants liked this approach for gaining access to hard-to-reach spaces: to hang artwork (“for high surfaces to hang things as well would be really really great. I do printing and I just want to hang it way up— I usually have to climb a friend’s shoulders or something”, P5), or to place or remove flyers (“I could see that being useful for large scale things— you could be commanding it what to do and not have to be climbing stuff... you can put flyers up higher, you don’t have to be climbing, and for that matter also removing things”, P3). In addition, the technique affords flexibility “on a surface where you didn’t have its [WallBot’s] path mapped out ahead of time – so you just kinda tell it where to go as you see it. Like the side of a building for example, you could tell it to climb around the windows” (P4). P5 also envisioned an audio-paint artwork: “I would just want to paint on it... and to think of it as another medium of the voice as paint. If it’s just dipped in paint- and I’ve never made a painting with my voice”.

### *Cellphone/Website (Explicit, Off Surface)*

In this scenario, we explore remote control of WallBots through cellphones (within view of the WallBot) or a website (removed from the WallBot). Several participants liked the implied anonymity of cellphone control in three contexts: 1) real-time social commentary, “you could be commenting on whatever is happening right now, but anonymously... it could be instant and reacting to whatever is happening” (P3); 2) street performance, “if you’re playing and it’s coming from behind them [the audience] or above them or something and you wanted it to move into their field of vision but you didn’t want them to know that you’re controlling it” (P6); and 3) bypassing security, “because of the security it would be a lot less shady than people running around with random lights – they might not even notice it” (P4). Website (completely remote) WallBot manipulation was interpreted primarily as a means of publically communicating with other people, for instance P5 would “want to communicate with my friends somehow all over the world through these little things”. P5 also noted that a community of artists could leverage WallBots to “Make the same thing but in different cities. And the fact that we make the same thing using the same device would connect us in a way”. Similarly, P3 suggested “Somebody having a public space but whatever they put on their Twitter message actually shows up large and they’re controlling it from their computer”.

### *Following a Person (Implicit, Off Surface)*

This is one of two examples illustrating our category of implicit, off surface interactions whereby WallBots react to ambient events in their surroundings. In the corresponding video, a WallBot followed a person walking next to a whiteboard. P1 and P3 suggested using this approach as an “interactive thing for an interesting humorous artwork”, especially in a museum or science center, “to kind of show off the robot itself”. P4 envisioned combining flash and long exposure photography, similar to the previous gesture interaction concept: “if you fire a flash at any time during the photo... you catch the person frozen in the frame but the light [from the WallBot] would still be going the whole time and you could have several different images of the person and you’d be able to see that it was following them”.

### *Ambient Sound (Implicit, Off Surface)*

This second example of implicit, off-surface interaction demonstrates a WallBot reacting to ambient sounds such as footsteps, traffic or a crowd cheering with unique movements. Participants commented on the autonomous behavior embodied by this approach: P5 noted that “you can almost disassociate yourself from it if it responds to things like car horns”, and P4 “could see something like that downtown where you just let it go by itself and it autonomously figures out what to draw based on the sounds that are around, free of any input from me”. P6 also suggested that the WallBot “dance or react to music – I think that one has pretty outstanding possibilities”. Lastly, P5 noted that the WallBot could “respond to art- to things

that it sees because then it gives it a role in a community of art. And it could be known as this robot that not only helps to make art but also has taste. But then it becomes totally anthropomorphized.”

### **WALLBOTS IN THE HANDS OF ARTISTS AND ACTIVISTS**

The final part of our study asked participants how they would use WallBots if these robots were available for free or at a low cost. Participants tended to discuss ways by which they would personally repurpose WallBots for their needs, using words such as “attach”, “make”, “fix”, “build”, “command”, and “program”. P5 also verbalized (without prompt) that “If you wanted to empower people and for them to use it, then yea make instructions and make it available”. We now present participants’ specific suggestions for our technology in the domains of street music, graffiti, political activism, and light-graffiti.

#### **Street Music**

Drawing a crowd poses a challenge for street musicians, so it is not surprising that P6 suggested using WallBots to make performance more interactive: “sometimes you feel like you’re doing something and people choose to watch... if they just want to listen they’re not really interacting, but if there was something else to hold their attention that might be useful.” Hence, P6 saw WallBots as a means for holding a captive audience, to “add something to the performance— so if there’s a way to *program* it so that it kinda fits what you’re doing”.

#### **Graffiti**

As one of the most defiant forms of street art, graffiti invites WallBots for their “factor of invisibility” (P5). Having a robot that creates graffiti “changes everything because it places the responsibility in an invisible place. I like that about it” (P5). Both P1 and P5 naturally saw WallBots as a tool for placing art in higher, hard-to-reach spaces: “I’d try to *attach* something to it and I would put it on a wall that’s a little bit higher- harder to reach by ladder...”. Lastly, P1 also commented that the WallBot itself is a type of graffiti: “I’d leave it in a public place just for people to see. It is almost like graffiti, it’s gonna catch the attention— they’re gonna almost be in that awed state— oh wow what is that”.

#### **Political Activism**

Both of the activist participants suggested using WallBots to express messages on larger-scale surfaces, as well as higher up: “to be able to *command* it beyond where you’re able to normally reach. You could set up a scaffolding or you could bring a robot and tell it what you want it to do” (P3). In addition, P3 noted that the act of using a WallBot would be effective in itself: “it would be such an attention getting thing. You have 100 flyers up but if you have a robot telling your story...” Lastly, P5 suggested WallBots as a tool of defiance, recalling and experience of police control during a peaceful protest: “We were very violently stopped... I don’t know if responding with a robot is helpful, but internally I did sort of have this feeling of

wanting to penetrate this barrier. These are things that would be capable of doing that. I think of them as tiny messengers that go places that I can’t”.

#### **Light Graffiti**

Light painting is inherently constrained by accuracy, as P4 explained: “when you’re drawing in the air or whatever, you can’t see what you’ve already drawn, so accuracy is very limited. I can’t go back and touch something up- see where a line started to finish it”. Having robots with built-in lighting empowers long-exposure photographers to capture precise designs that can not be hand-drawn: “If you had something like that... it’s infinite what you can do – you can reproduce anything”. To achieve this effect, P4 said, “I’d *make* it [WallBot] a little bit larger just so that I could *fix* a larger weight to it. P4 was enthusiastic about using WallBots in the future: “the potential applications for what I do is just the next level— like it’s between me scribbling in the air and recreating the Mona Lisa”.

### **DISCUSSION**

Our findings suggest a complex range of values and uses of public spaces by artists and activists. We now highlight four themes that came across in our interviews: anonymity, authorship, appropriation of space, and DIY methods.

#### *Anonymity*

To varying extents, all participants work under a veil of anonymity: they do not use real names, and most place their work and step aside, watching people’s reactions from afar. Much be said about this paradoxical desire to remain invisible while placing content in the most visible spaces. Naturally, P1 and P5, who author spaces with graffiti, spraypaint, and other permanent mediums, are most concerned about getting caught. Legal constraints shape their practices, positioning graffiti on the “lower” parts of bus stops, causing artists to work faster on lit streetpoles, and avoid certain surfaces altogether (ie. elevators with cameras). The work of a street musician embodies anonymity in a different sense. The practice (playing music) is itself in plain site, but its temporality leaves the artist unnamed: when a performance ends, the space is reclaimed as if the music was never there. From this stems the street musician’s greatest challenge: he must compete with traffic, noise and general apathy to draw a crowd amongst strangers who know him only through his ephemeral contribution to the space, here and now. These practices of remaining nameless lead to interpretations of WallBots as tools of “invisibility” that allow anonymous placement of content, naturally drawing our participants to prefer WallBot interactions that are implicit, removed from the robot, the surface or even the space altogether.

#### *Authorship*

While public activists and artists remain unnamed, they symbolically claim authorship of their work and thrive on public attention. The graffiti artists (P1, P5) and the light painter (P5) sign their pieces with a symbol that is known and recognized throughout their communities. Moreover, all six participants enjoy eliciting reactions to their work:

from shock and admiration of reaching a high space, to causing someone to stop and ‘breathe’, to increasing rally attendance or voter registration, participants want to impact and shape their environment. This desire to restructure public spaces inspires participants’ appropriations of the WallBot as a means of drawing attention. For the graffiti artist, the WallBot is a tool to access a higher, more ‘surprising’ place; for the light painter, the WallBot serves as a precise ‘paintbrush’; for the street musician, the robot morphs into an interactive performance accessory; and for the activist, it communicates across larger surfaces, becoming part of the message itself. The ways in which participants envision using WallBots stem from their goals, which in turn dictate the surfaces they choose to work with.

#### *Appropriations of Space*

All six participants are against altering what they perceive to be personal space-avoiding graffiti on “private cars” or residential homes, not performing in public transport where people can not ‘opt-out’, and feeling compelled to ask for permission to post flyers on building walls. At the same time, participants consider spaces such as bus stops, street poles, elevators, and corporate buildings to be acceptable sites for expression. The “foot traffic” associated with these spaces is both an asset and a challenge – a political message might be noticed, but a graffiti artist may get caught and a street musician might be ignored. Moreover, some participants’ use of space reflects societal rules: while a garbage can serves as a canvas for graffiti and light painting, a political flyer placed on the same medium may suggest negative implications for the message. Issues of access, privacy, and social convention cause participants to interpret WallBots as robots that go where people cannot. Hence, with-WallBot interactions are not considered useful- if users can directly interact with the object, they can also reach the underlying space and have less need for the technology.[??] On and off surface interactions distance the owner from the WallBot, allowing for expressions in spaces that are otherwise inaccessible.

#### *DIY Methods and Mentality*

Given that all six individuals reshape public spaces, it is not surprising that they also choose to create, repurpose and reuse the tools and materials that facilitate their expressions. While for P1, DIY is a means to save money on paints, markers, etc., for P5 reuse becomes an artform in itself, turning shredded paper into a “dancing flurry”, or dead leaves into a medium for poetry. Because participants tend to create or alter the materials they work with, they receive WallBots as artifacts that, in their words, they can “fix”, “make”, “command”, or “attach” things to. Rather than being viewed as mere tools to perform a task, WallBots are welcomed as part of the artform itself, interpreted as “little messengers”, “performative” (during draw input), “dancing or reacting to music” (during ambient sound interaction), or a means to “connect” people around the world if they create content through the same means (manipulating WallBots remotely).

## **DESIGN IMPLICATIONS AND FUTURE WORK**

Our findings suggest design implications for technologies that liberate grassroots artists and activists from constraints and limits imposed on their work. We focus on kinetic, magnetic systems that facilitate a ground-up reorganization of space, restructuring the relationship between the artist or activist and the public surface. In this context, we highlight the importance of flexible, low-cost DIY technologies, motivated by participants’ current practices of reuse and repurpose, their enthusiasm for modifying WallBots by hand as well their financial needs. As mediums and tools for expressions, future systems must place design decisions and functional control in the hands of the user, allowing for easy modification, restructure and repurpose. Moreover, given the wide range of surfaces used by artists and activists, future technologies must be modular and easily deployed on walls, bus stops, streetpoles, trashcans, etc. We now present specific design implications and research opportunities in the context of graffiti, street music, political activism and light graffiti.

#### *Graffiti*

The graffiti artist is constrained by political and spatial boundaries, seeking expression in physically inaccessible and socially or legally forbidden spaces. Her practice is hidden, but her work strives for attention, permanently embedded on any surface that can be reached without getting caught. Naturally, an autonomous wall-crawling robot presents opportunities for drawing attention to the work without exposing the artist. This attention could be achieved both by enabling artforms on harder to reach spaces (heights, fenced in areas, etc), as well as by the unexpected presence of the technology itself (i.e., the WallBot as a ‘type of graffiti’). Anonymity can be preserved through implicit and/or off-surface interactions that conceal the robot owner from the general public.

#### *Street Music*

The street musician is almost diametrically opposed to the graffiti artist, aspiring to draw public attention to the act of authorship rather than its lingering aftereffects. His or her relationship to the space is temporal, and the spatial contribution— ephemeral. In the 19<sup>th</sup> century, the organ grinder beckoned crowds with a performing monkey. Today, technologies present a low-cost, DIY and better-behaved alternative. Wall-traversing autonomous agents form a creative extension of the artist, suggesting opportunities for live interactions between performer, audience and machine. Future work can explore multiple modalities, for instance robots that not only move but also paint on vertical surfaces based on explicit or implicit input.

#### *Political Activism*

For the activist who can freely post flyers on the most visible surfaces (bus stops, streetpoles, etc), it is not enough for a message be noticed. Its placement and content must compel the viewer to vote, to attend a rally, to call a local official, to *react* in ways that further the activist’s goal.



Urban spaces become mediums of persuasion, challenged by public apathy and lack of awareness. Here, magnetic kinetic systems present an opportunity to engage the viewer in the political dialogue, to combat ignorance with insights into the cause and to transform indifference into action. The robot must therefore ‘tell the story’, enabling a message to evolve through space, fluidly engaging the observer with direct and implicit interactions.

### *Light Graffiti*

The light painter draws in plain site, but his work is invisible: sketching in the air, on building walls, trashcans, bus stops, or park benches, he creates designs that are only captured through the lens of his camera. His paintbrush is a flashlight, a glowstick, a match, a light pen, a candle—with these he flirts with space, developing a relationship that is both fleeting and permanent. Kinetic systems can converge with the craft, liberating the light painter from his greatest challenge: precision. Autonomous agents, wielding a range of light ‘brushes’ from bright LED’s to luminescent bulbs, or flaming torches, can be programmed to create intricate designs that can not be achieved by hand on surfaces that have previously remained inaccessible. Future work can explore intuitive interactions for precisely controlling such systems, as well physical designs that enable easy placement and activation of light ‘paint’ on wall-traversing robots.

### **CONCLUSION**

We presented an exploration of the methods and practices behind street art, constructing a dialogue between HCI research and the people and processes that shape our cities. Our technical intervention introduces autonomous, wall-crawling robots as an approach for novel activations and interactions on vertical surfaces. Placing WallBots in the hands of public artists and political activists reveals a design space for magnetic kinetic systems as a medium of public expression, persuasion and performance. We hope that our work inspires future projects that engage academic research with grassroots public art and activism, empowering HCI to converge with the bottom up practices that embody urban aesthetics.

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